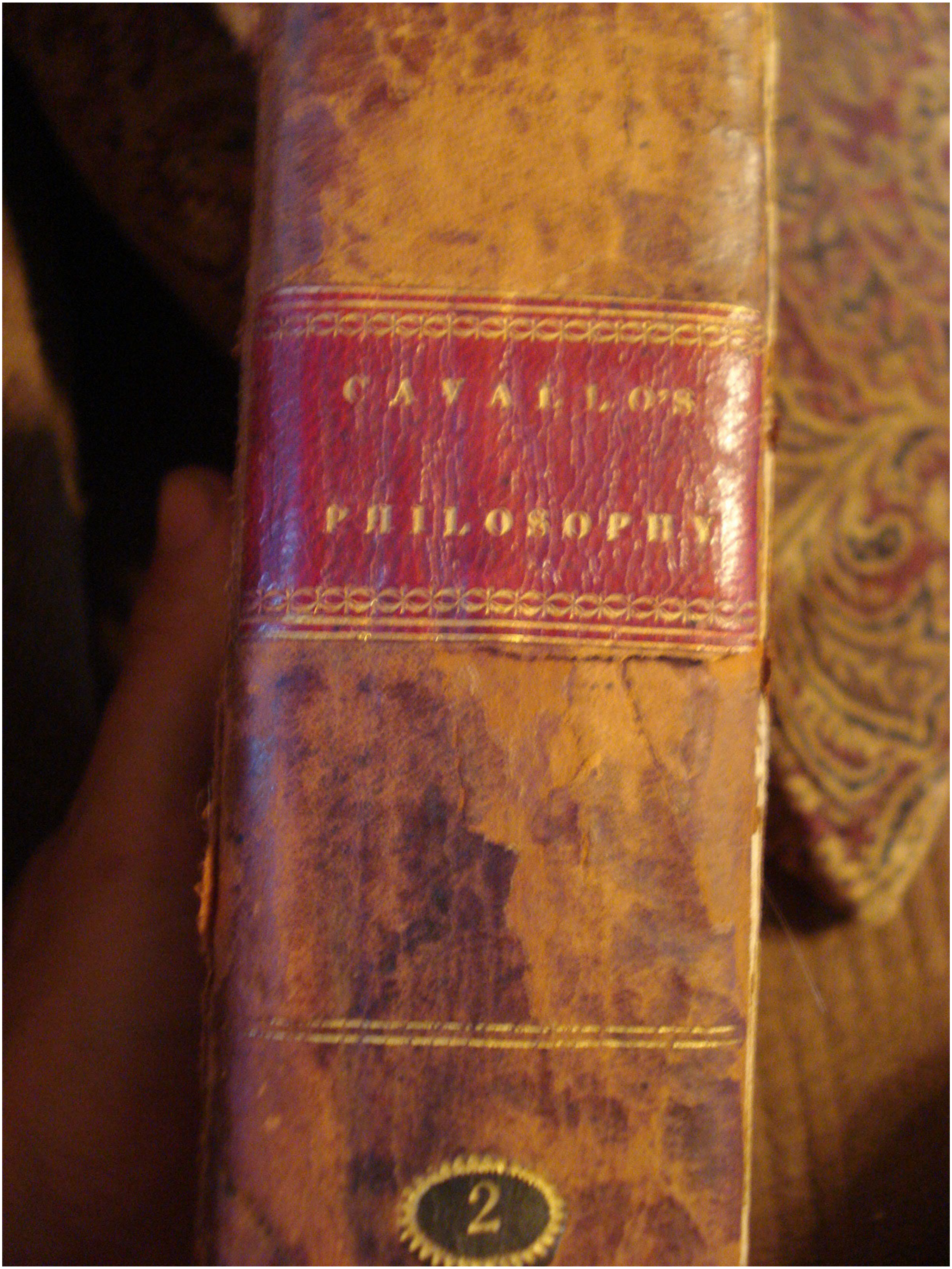

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THE

ELEMENTS

OF

NATURAL OR EXPERIMENTAL

PHILOSOPHY.

BY TIBERIUS CAVALLO, F.R.S. &c.

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BY F. X. BROSIUS.

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CHAPTER VIII.

Natural Phenomena relative to Light.

116. WE have reserved for this chapter the account of such natural phenomena respecting light, as could not be inserted in the preceding chapters, without interrupting the general theory of optics.

The *rainbow* is undoubtedly the most frequent, the most remarkable, and the most generally known, of those phenomena. We shall, in the first place, state the particular circumstances that attend its appearance, and then subjoin the usual explanation.

When the sun is on one side of the spectator, and rain falls on the other side, a beautiful coloured arc is frequently seen in the sky on the side of the rain. This coloured arc is called the *rainbow;* and often two such arcs are seen one within the other.

The colours of the inner bow are much more vivid than those of the outer bow. Each bow exhibits all the prismatic colours, arranged in the same manner as in the prismatic spectrum, viz. red, orange, yellow, green, blue, indigo, and violet; but the order of those colours in the upper bow is contrary to that of the lower; the latter having the violet below and the red above, whilst the former has the red below, and the violet above. Those colours are blended into each other, so that no eye can distinguish their boundaries; and indeed for most eyes it is difficult to distinguish more than the three or four more predominant colours.

Sir Isaac Newton calculated the breadth of each bow, as also the distance between them; but on the supposition that the light which comes from the sun and forms the bows amongst the drops of rain, came from a single point, viz. from the centre of the sun. The result of that calculation is, that at the eye of the observer, the breadth of the internal or lower bow should subtend an angle of 1° 45′, and the breadth of the external, an angle of 3° 10′, and that the distance between the two bows should subtend

an angle of 8° 55′. But as the sun is not a point, and as the light proceeds from every part of its surface, the diameter of which subtends an angle of about half a degree; therefore the breadths of the bows are larger, and the distance between them is less than the above-mentioned results.*

The situation of the rainbows changes according as the eye of the spectator changes situation; for otherwise their breadths, &c. could not subtend constantly the same angles; hence no two persons can see the same bow precisely, or the same colour, in the very same place.

When the spectator is upon a plain, and the sun is close to the horizon, the rainbow is a semicircle; but, according as the sun is higher above the horizon, so the rainbow is a smaller part of a circle. The inner or lower bow cannot appear when the elevation of the sun exceeds 42°; and even the upper bow disappears when the elevation of the sun exceeds 54°.

When the spectator is upon an eminence, and the sun is near the horizon, then the rainbow may exceed a semicircle; and if the elevation of the spectator be very great, and the rain near him, then the rainbow may form a complete circle: for in all cases the centre of the bow, the spectator, and the sun, must be in the same straight line, which is called the *line of aspect*.

The rainbow sometimes is complete from one part of the ground to the other; and at other times it is interrupted, either in the middle or in some other part. This happens when the rain is partial; for it is in the drops of rain that the bows are formed, or that the light is dispersed into

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* Actual measurement with a quadrant, when the colours are vivid, constantly shows that the breadth of the lower bow subtends an angle 2° 15′; the breadth of the upper bow subtends an angle of 3° 40′, and the distance between both bows subtends an angle of 8° 25′. Also the semidiameter of the circle, of which the external part of the lower bow is an arc, subtends an angle of 42° 17′; and the semidiameter of the circle, of which the internal part of the upper bow is an arc, subtends an angle of 50° 42′.

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its coloured rays. The interruption, however, may also be produced by the interposition of clouds, &c.

It follows likewise, from the various distances of the rain, and from the wind, which impels the rain obliquely, that sometimes the rainbow appears inclined, or even of an oval form.

117. The usual way of accounting for the formation of the rainbow, or for the dispersion of white light into colours, amongst the drops of rain, is as follows:

Let stD, fig. 67., represent a drop of water in the sky. Ss is a beam of the sun's light that falls upon it. This ray, on account of the refractive power of water, will not proceed straight towards F, but will be bent towards the perpendicular sC, so as to impinge upon the surface of the drop at t. At that place part of the light passes through the drop into the air; but another part of it is reflected, making the angle of reflection equal to that of incidence, and in coming out of the water into the air at e, is refracted, viz. bent from the straight direction ef, so as to make the angle peO, with the perpendicular Cp, larger than the angle Cet (61.). In short, the beam of light Ss, by going in and out of the drop, suffers two refractions, viz. at s and e, and one reflection at t. By calculating the directions it must take at those places, (according to the method described in art. 68.) it will be found that the angle SFO is $42^\circ\ 2'$.

By these refractions the light is (62.) dispersed into the prismatic colours OeB; the red light, as the least refrangible, being next to eO, and the violet next to eB; therefore an eye situated at O will perceive a red light at e. If the eye be raised gradually higher, it will perceive the orange next, then the yellow, then the green, &c. and last of all will perceive the violet.

Now this would be the case if there were a single drop of rain in the sky, and that drop remained immovable: but it is easy to conceive that if the eye of the spectator remain immovable, and the drop descend gradually from C to E, then the eye will likewise perceive all the colours successively, from the red to the violet; and since, in a shower of rain a vast number of drops are to be found at

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the same time between C and E; therefore the eye will at the same time receive the red light from the drops at C, or near it, the orange from drops that are a little lower, the yellow from those that are lower still, &c.; and, lastly, the violet from the lowest at E. Hence the violet, which is seen in the direction OE, is the lowest colour of the first rainbow; and the red, which is seen in the direction O*e*, is the highest.

Since the incident and the refracted ray must make a given angle, as SFO, in order to show a certain colour; it follows, that the rainbow must be the arc of a circle, or rather the base of a cone, the axis of which (viz. the *line of aspect*) passes through the eye of the spectator, and through the sun, which forms the vertex of the cone; for in that case only straight lines drawn from any point of the rainbow to the sun, and to the eye of the observer, from the same requisite angle. Hence we see why, when the line of aspect is upon the horizon, the bow must be a semicircle; also, why it must be less than a semicircle, when the line of aspect is inclined from the sun downwards, &c.

Having spoken above of the incident ray, or beam of light S*s*, it may perhaps be necessary to observe, for the sake of perspicuity, that this is not the only light that falls from the sun upon the drop *st*D; for there are numberless rays that fall upon its whole surface; but as they fall with different inclinations, so all their emergent parts cannot come to the same eye: hence we have taken notice of that light only, which impinging upon the drop in the direction S*s*, can (after the two refractions at *s* and *e*, and a reflection at *t*,) come to the eye at O.

There is, however, another part of the light incident upon a drop of rain, which, after two refractions, and two reflections, can come to the same eye when placed at a proper distance; and this is the light which forms the second or external rainbow.

Let *d*G*s* (fig. 67.) be a drop of rain higher than the drop *st*D. Y*s* is a ray of light, which enters it at *s*, and instead of proceeding straight towards *a*, is refracted towards the perpendicular *s*C; it is then partly reflected

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from *d* to *e*, and again from *e* to *g*; making both at *d*, and at *e*, the angles of reflection respectively equal to the angles of incidence. Lastly, on going out of the drop at *g*, this ray is refracted from the perpendicular *q*C, and is dispersed into the coloured sector B*g*O, having the violet colour, which suffers the greatest refraction, next to B*g*; and the red, which is the least refrangible, next to *g*O; so that the colours of the upper rainbow are in an order contrary to that of the lower rainbow. By calculating the changes of the direction which take place at the two places of refraction, *s*, *g*, and at the two places of reflection *d*, *e*, it will be found that the emergent red ray *g*O, makes with the incident ray Y*h*, an angle O*h*Y of 50° 57′.

On account of the light suffering one reflection more, and continuing longer in the drop G*ds* than in the drop *st*D, the angle of dispersion B*go* is larger than the angle of dispersion O*e*B: hence the upper rainbow is broader than the lower; but its colours are not near so vivid as those of the lower.

I need not repeat what has been said above in explanation of the particulars relative to the form, extent, &c. of the lower rainbow; for the same explanation, with few obvious changes, is applicable to the upper rainbow. See note E.

A rainbow, much less vivid than the former, is also produced, and for the same reasons, by the light of the moon.*

Such a coloured bow is not unfrequently seen at sea in the spray or drops of water, which the wind disperses or carries away from the tops of the waves. The colours of this bow are not so lively as those of the common rainbow; the most vivid are a yellow next to the sun, and a green next to the sea. Those bows, of which a great many are often to be seen at the same time, have a position contrary to that of the common rainbow; viz. the curve part is towards the sea, and the legs upwards.

A coloured bow is always to be seen amongst the scattered water of a jet, a broken cascade, and the like, when the sun and the spectator are in proper situations.

Sometimes a coloured bow is caused by the refraction of the

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* See the account of a remarkable lunar bow in the Phil. Trans. No. 331.

sun's rays in the drops of dew upon the grass. The convex part of such bow is turned towards the spectator.

In short, a coloured bow, larger or smaller, stronger or weaker, according to circumstances, is always to be seen when drops of water, the sun, and the spectator, are properly situated. A person may see it if he turns his back to the sun, and forces some water violently, and in broken streams, from his mouth. But the best way of imitating a rainbow is to fasten a number of small solid glass balls, or a number of small glass bubbles full of water, upon a dark board, and to present the board thus furnished to the sun at a proper inclination, which experience easily finds, whilst you turn your back to the sun, and look at the board.

118. Another sort of luminous appearances under the name of *halos* or *coronas*, may be frequently observed in the sky. These are circular zones of pale light, mostly white, but sometimes variously coloured, which are seen round the sun, the moon, and even round some very bright star or planet. The halo is sometimes quite close to the luminous body. "Those which have been seen about Sirius and Jupiter were never more than 3, 4, or 5 degrees in diameter; those which surround the moon are, also, sometimes no more than 3 or 5 degrees. But these, as well as those which surround the sun, are of very different magnitudes, viz. from 12° to 90°, or even larger than this. Their diameters also sometimes vary during the time of observation; and the breadths both of the coloured and white circles are very different, viz. of 2, 4, or 7 degrees.

"The colours of these coronas are more dilute than those of the rainbow; and they are in a different order, according to their size."

Coronas may be produced by placing a lighted candle in the midst of steam in cold weather.

Various opinions have been entertained by different philosophers concerning the real causes of such halos or coronas. But whether they are owing to the refraction, or the reflection, or the inflection of light, or to all those causes, and in what proportion, is not yet satisfactorily determined. It appears, however, that they are formed in such aggregations of vapours as are not heavy enough to fall in the form of drops.*

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* Descartes remarks, that halos never appear when it rains. Dioptrics, page 230.

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119. A more remarkable, but much less frequent, species of phenomena are sometimes seen in the heavens; they are called *parhelia* and *paraselenes*, vulgarly called *mock-suns* and *mock-moons*. They seem to be reflections of the sun and of the moon from zones of dense vapours that happen to be collected in the sky.

Parhelia have been seen and are mentioned by various authors.*

"The apparent size of parhelia is the same as that of the true sun; but they are not always round, and also, they are not always, though they are sometimes said to be, as bright as the true sun. When there are numbers of them, some are not so bright as others. Externally they are tinged with colours, like the rainbow, and many have a long fiery tail opposite to the sun, but paler towards the extremity. Dr. Halley observed one which had tails extending both ways, and such a one also M. Muschenbroeck observed in 1753, the tails being in a right line drawn through both the suns. Both of them, also, were in coloured circles. M. Weilder saw a parhelion with one tail pointing upwards and another downwards, a little crooked; the external limb, with respect to the sun, being of a purple colour, and on the other side it was tinged with the colours of the rainbow. The tails of these parhelia, for the most part, appear in a white horizontal circle.

"Coronas generally accompany parhelia, some tinged with the colours of the rainbow, and others white. They differ in number and size, but they are all of the same breadth, which is that of the apparent diameter of the sun.

"A very large *white circle*, parallel to the horizon, generally passes through all the parhelia; and if it were entire, it would go through the centre of the sun. Sometimes there are arcs of lesser circles concentric to this, touching those coloured circles which surround the sun. They are also tinged with colours, and contain other parhelia."†

120. Of the *aurora borealis*, or *northern light*, we shall make mention in the next section, under the title of Electricity: but we shall just observe in this place, that sometimes, though by no means frequently, a pale white light more or less extended, is seen in the sky, the cause of which is not known. It differs from the northern light principally by its being steady and uniform, whereas the northern light is lambent and changeable. The former is

* Aristotle, Pliny, Gassendi, De la Hire, Cassini, Descartes, Newton, Mr Grey, Dr Halley, &c.

† Priestley's History of Vision, Light, and Colours.

likewise more dense than the latter; for it generally eclipses the stars over which it passes. A remarkable appearance of this sort was observed in London on the night of March the 27th, 1781.*

121. The *zodiacal light* is a sort of pyramidal whiteness, which is sometimes seen above the horizon after the setting of the sun, or before its rising. Its whiteness is not much unlike that of the *via lactea*, or *milky-way*. Its base is towards the sun, and its extension is in the plane of the zodiac. Cassini seems to have first taken notice of it in 1683. In the torrid zone the zodiacal light is frequently, or almost constantly seen. At or near our latitude it may be seen about the time of the equinoxes. The breadth of this whiteness is various; at the horizon it varies from 8 to 30 degrees; its extension, reckoning from the sun to the apex of the light, generally exceeds 45°. Mr. Pingré, being in the torrid zone, saw it of 120 degrees.

"At present, says de la Lande, it seems to be generally believed, that the zodiacal light is the atmosphere of the sun; for it always accompanies that luminary, and the equator of the sun is in the direction of the zodiacal light. Therefore in all probability the zodiacal light is an atmosphere situated round the sun in the direction of its equator, and flattened by its rotatory motion."

122. Various accounts of peculiar luminous appearances that are seen in particular places, and which are evidently owing to certain peculiar dispositions of mountains, houses, rivers, and other objects, are to be met with in different books; but none of these seems to be more remarkable, and less understood with respect to its cause, than the famous *Fata Morgana*, or apparition so called, which is frequently seen near the city of Reggio, situated towards the extremity of the kingdom of Naples, and facing the island of Sicily.

"When the rising sun shines from that point, whence its incident ray forms an angle of about 45 degrees on the sea of Reggio, and the bright surface of the water in the bay is not disturbed either by the wind or the current, the

* Philosophical Transactions, vol. LXXI. Art. 16.

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spectator being placed on an eminence of the city, with his back to the sun and his face to the sea;—on a sudden there appear in the water, as in a catoptric theatre, various multiplied objects, viz. numberless series of pilasters, arches, castles well delineated, regular columns, lofty towers, superb palaces, with balconies and windows, extended alleys of trees, delightful plains with herds and flocks, armies of men on foot and horseback, and many other strange images, in their natural colours and proper actions, passing rapidly in succession along the surface of the sea during the whole of the short period of time while the above-mentioned causes remain.

"But if, in addition to the circumstances before described, the atmosphere be highly impregnated with vapour, and dense exhalations not previously dispersed by the action of the wind or waves, or rarefied by the sun, it then happens that in this vapour, as in a curtain extended along the channel to the height of about 30 palms, and nearly down to the sea, the observer will behold the scene of the same objects not only reflected from the surface of the sea, but likewise in the air, though not so distinct or well defined as the former objects from the sea.

"Lastly, if the air be slightly hazy and opake, and at the same time dewy and adapted to form the iris, then the above-mentioned objects will appear only at the surface of the sea, as in the first case, but all vividly coloured or fringed with red, green, blue, and other prismatic colours."*

This phenomenon is related with some variety of circumstances, and has been differently explained, by various writers. Upon the whole, it seems that the appearances of houses, trees, &c. are only the reflections of the objects of the city of Reggio, and of the coast. They seem to be reflected from the surface of the sea, and from the surface of dense vapours or clouds in the air close to the sea; and according to the various forms and number of the reflecting surfaces, those objects are multiplied, magnified, inverted, elongated, or otherwise distorted. But the exact explanation of the phenomenon must be left for the ingenuity of future observers.

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* *Dissertatizone prima sopra un Fenomeno volgarmente detto Fata Morgana. Del P. Antonio Minasi. Roma* 1773.

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123. I shall close this chapter with a concise account of phosphorescent bodies, among which I shall reckon the *ignis fatuus*, or *jack-a-lantern*.

The name of phosphorus has of late been given to a particular primitive substance, of which mention has been made in Part II. Chap. XV.; but in its more extensive application, that name means every substance that shines in the dark, without the production of sensible heat.

The phosphorescent bodies may be divided into five species, viz. I. The living animals which have the property of shining in the dark, such as glow worms, lantern flies, of which there seems to be several species, but of the mechanism which produces their light, nothing certain is known. In this country some of them, in their best state, afford light barely enough to read the hour on a watch that has a clear dial. In warmer climates their light is much more powerful. The light of those insects generally ceases after death; but whilst living they may either show it or not at pleasure.

II. Those bodies which absorb light, and then yield it in the dark.

A vast number of substances have the property of shining for a certain time in the dark, after having been previously exposed to light; but they have it in different degrees of intensity as well as of duration. Several precious stones, and calcareous bodies, especially after calcination, have this property, as also paper, and almost all vegetable and animal substances when very dry, or after solution in nitrous acid. Metallic substances and water have not this property; yet congealed water, viz. ice, and especially snow, have it in a considerable degree.*

There is a mineral, called the *Bolognian stone*, which, after due preparation, has this property in a very remarkable degree.† Those

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* Becari's Experiments in the Comment. Bonon. vol. V. page 106.

† The proper or effectual method of preparing this stone seems to be kept secret. Several trials made in this country have succeeded but partially. Kircher directs us to reduce the stone into a fine powder, together with white of egg, water or linseed oil. The

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stones are mostly found in the neighbourhood of Bologna. This is a heavy gray spar of the barytic genus, properly called *baroselenite*, and, from its weight, *marmor metallicum.*

If this stone, after due preparation, be exposed to the day light, and then be brought into a dark room, it will be found to shine with a darkish red light, or to appear like ignited coals. This shining continues a few minutes, gradually decaying, and lastly vanishing. By exposing it again to the day-light for a few seconds, its shining property is renewed as often as one pleases. It will become luminous even by exposing it to candle light.

The residuum of the distillation of chalk and nitrous acid has the shining property, similar to that of the Bolognian stone, though not in so great a degree. This is called (from its inventor) *Baldwin's phosphorus.*

Several other preparations have the property of absorbing light, and then of yielding it in the dark; but none has it in so eminent a degree as that which was discovered by the late Mr. Canton, and which is prepared in the following manner:

"Calcine some common oyster-shells," (if they be old, and half calcined by time, such as are found upon the sea-shore, they are so much the better) "by keeping them in a good coal-fire for half an hour; let the purest part of the calx be pulverized and sifted; mix with three parts of this powder one part of the flowers of sulphur; let this mixture be rammed into a crucible of about an inch and a half in depth, till it be almost full; and let it be placed in the middle of the fire, where it must be kept red hot for one hour at least, and then set it by to cool; when cold, turn it out of the crucible, and cutting or breaking it to pieces, scrape off, upon trial, the brightest part, which, if good phosphorus, will be a white powder, and may be preserved by keeping it in a dry phial with a ground stopple."*

If this phosphorus, whether in the phial or not, be kept in the dark, it will give no light, but if it be exposed to the light, either of the day, or of any other body sufficiently luminous, and afterwards be brought into a dark place, it will appear luminous for a few minutes. It light is white with a shade of blue or green.

A little of this phosphorus, when first brought into a dark room, after having been exposed for a few seconds on the outside of a window to the common day light, will give light enough to discover the hour on a watch; provided the eyes of the observer have been shut or in the dark two or three minutes before.

It has been long questioned whether those phosphori shine by yielding the light which they have first imbibed, or by yielding

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paste thus formed must be put in a furnace, and must be calcined to a certain degree. Others direct to place the Bolognian stone amongst lighted charcoal, and to leave it undisturbed therein until the coals are consumed.

* Philosophical Transactions, vol. LVIII. page 337.

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their own light, kindled as it were by the action of foreign light; and though the former opinion be by far the most probable, yet the question is not quite satisfactorily determined.

In order to elucidate this point, various ingenious persons have attempted to illumine those phosphori by coloured light, as for instance, by red, or green, or blue, or yellow light; but their results do not agree. Algarotti having illuminated the Bolognian phosphorus, by differently coloured light produced by a prism, found that the phosphorus was faintly illuminated by this means, but he could not distinguish any difference of colour in it.*

The de ermination of this question would go a great way towards proving that light is real matter emanated by the luminous body, rather than a modification of a fluid universally dispersed. But independent of this question, what principally seems to prove the materiality of light, is the change which light alone produces on various bodies, viz. on vegetables, on solutions of silver, &c.†

III. The bodies which produce light when heated, form the third species of phosphorescent bodies. The best method of heating bodies in a dark room for this purpose, "is to reduce the body to a moderately fine powder, and to sprinkle it, by small portions at a time, on a thick plate of iron, or mass of burnt luting made of sand and clay, heated just below visible redness, and removed into a perfectly dark place."‡

A great variety of substances shine when they are so treated, viz. fluoric stones, several marbles, diamond and other precious stones, calcareous earth, metallic substances, sea coal, oils, wax, butter, paper, and several other animal and vegetable substances.

The phosphori of this species give out light and heat, without the necessity of having been previously exposed to external light.

IV. Several substances yield a light either quite white, or with different shades of red, or blue, by attrition, viz. when they are rubbed or knocked one against the other. The light is generally spread beyond the touching parts, and sometimes it spreads all over the bodies.

Almost all the stones of the siliceous genus, such as quartz,

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* Acad. Par. 1730.

† See Count Rumford's Paper in the Philosophical Transactions, volume for the year 1798, Art. XX.

‡ See Mr. T. Wedgwood's Paper in the Philosophical Transactions, volume for the year 1792, Art. III.

flints, agates, &c. have this property, as also glass, porcelain, hard baked earthenware, &c.

This light is often accompanied with a faint but peculiar smell. Some of those bodies during attrition, emit now and then reddish sparks of a vivid light, which retain their brightness in a passage of 1, 2, and even 3 inches through the air.

V. The phosphori of the last species are those which emit light whilst they are in an evident state of decomposition. Of this sort are most animal matters, and some vegetable substances, especially rotten wood. In some of them the light seems to belong to the extrication of phosphorus properly so called; whilst in others a pure light seems to be produced. Upon the whole it appears, that light enters into combination with various bodies, and forms one of their constituent principles, especially with animal and vegetable substances; and that when those substances are in a state of decomposition, the light being one of the ingredients, is separated from the rest, &c.

Of all the animals, fish seem to afford the greatest quantity of light, and they yield it in the greatest quantity before the putridity takes place. Almost every body is acquainted with the shining property of fish; but the most recent and entertaining experiments upon this species of animals, and particularly with the herring and the mackerel, were made by Dr. Hulme, and are described in the Philosophical Transactions for the year 1800, article IX. from which the following particulars have been extracted.

Herrings and mackerels (and probably most other fishes) begin to appear luminous about the second day after their having been taken out of the water. The light increases whilst they are perfectly good and sweet; but it begins to decrease when the fish begins to putrify, and it decreases according as the putrescence increases.

It is not the external surface only of those animals that is capable of shining; but the light seems to be incorporated with their whole substance, and to make a part thereof, in the same manner as any other constituent principle; for if the fish be cut in various pieces, the whole surface of every piece becomes luminous, if kept in a dark and rather cool place; especially the soft roe both of the herring and of the mackerel, which look like a complete body of light at about the third or fourth night, which generally is the period of their greatest brightness.

Hence it seems that the decomposition of the fish begins very soon, but the light is the first principle that escapes, and which takes place long before any fœtid or putrid effluvium can be perceived.

The luminous matter of fishes, or the thickish liquor with which

this light is incorporated, may be scraped off by means of a knife from over their surfaces, and may be preserved in a phial, where it will continue to shine for a day or two, or longer, according to circumstances. But there are some substances which, being mixed with this luminous matter in a certain proportion, will extinguish its light; and it is very remarkable that some of those very substances, but mixed in another proportion, will increase or preserve it for some time longer.

"Those which extinguish it are, water alone; water impregnated with quicklime; water impregnated with carbonic acid gas; water impregnated with hepatic gas; fermented liquors; ardent spirits; mineral acids, both in a concentrated and in a diluted state; vegetable acids; fixed and volatile alkalies, when dissolved in water; neutral salts, viz. *saturated* solutions of Epsom salt, common salt, and of sal ammoniac; infusions of chamomile flowers, of long pepper, and of camphor, made with boiling-hot water, but not used till quite cold; pure honey, if used alone."

On the other hand a very moderate solution of some of the above-mentioned substances, dissolved in water, and then mixed with the luminous matter of fishes, will render their light stronger and more durable.

"Two ounces of sea-water, being agitated with the light of mackerel, soon obtained a brilliant illumination. The sea-water preserved its luminousness for several days."

Any of the last-mentioned solutions, being impregnated with the luminous matter, and left some time at rest, are rendered more lucid by a moderate degree of heat, but a higher degree of heat, such as that of about boiling water, extinguishes them totally and permanently.

Cold extinguishes this light in a temporary manner; for the light is revived in its full splendour as soon as it is exposed to a moderate degree of heat.

The light of those mixtures is rendered more vivid by motion, viz. by agitating the phial which contains the liquor, or by drawing some hard body through it. This seems fully to explain the cause of that phosphorescent light which at night is seen on the surface of the sea, when the water is agitated by a high wind, or by the dashing of oars, &c.

When this luminous matter of fishes is extinguished by being mixed with some of the saturated solutions of the above-mentioned kind, its light is not totally lost, but it may be revived in its former splendour by converting the solution into one of the latter sort; for instance, if the light be extinguished by the admixture of a saturated solution of salt, add more water to the mixture, so as to diminish the proportion of salt, and the light is thereby revived; and on the contrary, if to the latter more salt be added, the light will be extinguished, and so on.

"Some shining matter," says Dr. Hulme, "was taken from a mackerel, and mixed with a solution of seven drachms of Epsom

salt in one ounce of water; and its light was immediately extinguished. The same effect ensued, but in a less degree, with a solution of six and of five drachms. In a solution of two drachms, in the same quantity of water, the liquid was luminous; but much more so when only one drachm of salt was used. Observing the extinction of light to take place, as above, in the more saturated solutions, while the diluted solutions were luminous, it occurred to me to endeavour to discover what became of the extinguished light in the former case, and whether it might not be revived by dilution. For this purpose I took the solution of seven drachms of salt in one ounce of water, in which the lucid matter from a mackerel had been extinguished, and diluted it with six ounces of cold pump water; when, to my great astonishment, light in a moment burst out of darkness, and the whole liquid became beautifully luminous! This revived light remained above 48 hours, that is, as long as other light in general does, which has never been extinguished. Hence, it had lost nothing of its vivid luminous powers by its extinction."

The flesh of quadrupeds sometimes has also been observed to emit light.* Light has also sometimes been seen on burying-grounds, which is attributed to the same cause, viz. to the decomposition of animal matter.

Vegetable substances in a state of decomposition, and especially rotten wood, are sometimes seen to shine in the dark; but amongst the various luminous appearances which seem to owe their origin to a decomposition of animal and vegetable matter, none is so famous, and yet so imperfectly known as the *ignis fatuus*, or *jack a-lantern*, which has been variously related by ignorance, apprehension, and exaggeration.

It has been the opinion of certain philosophers, that the *ignis fatuus* is produced by shining insects Sir Isaac Newton called it *a vapour shining without heat;* and this seems to be the most probable opinion, especially if it be allowed to owe its origin to the decomposition of animal and vegetable substances.

Waving, however, any further conjecture, I shall just add two of the most authentic accounts of such appearances that I find recorded.

It is related by Dr Durham, that, having observed an *ignis fatuus* in some boggy ground, between two rocky hills, in a dark and calm night, he got by degrees within two or three yards of it, and thereby had an opportunity of viewing it to the greatest advantage. It kept skipping about a dead thistle, till a slight motion of the air, occasioned, as he supposed, by his near approach to it, made it jump to another place; and as he advanced, it kept flying before him He was so near to it, that, had it been the shining of glow-

* See T Bartholin *de luce animalium*, p. 183. Boyle's Works, vol. III. p. 304. Phil. Trans. vol. XI. p. 599.

worms, he was satisfied that he could not but have distinguished the separate lights of which it must have consisted; whereas it was one uniform body of light. He therefore thought that it must be an ignited vapour.

Mr Becari made particular inquiry concerning the *ignis fatuus*. He found that two, which appeared on the plains, one to the north and the other to the east of Bologna, were to be seen almost every dark night, especially the latter; and the light they gave was equal to that of an ordinary faggot That to the east of Bologna once appeared to a person of his acquaintance, constantly moving before him, and casting a stronger light upon the road than the torch, which was carried along with him. All these luminous appearances gave light enough to make all neighbouring objects visible, and they were always observed to be in motion, but this motion was various and uncertain. Sometimes they would rise up, and at other times sink; but they commonly kept hovering about six feet from the ground. They would also disappear of a sudden, and instantly appear again in some other place. They differed both in size and figure, sometimes spreading pretty wide, and then again contracting themselves; sometimes breaking into two, and then joining again; sometimes floating like waves, and dropping, as it were, sparks of fire. He was assured that there was not a dark night all the year round in which they did not appear, and that they were observed more frequently when the ground was covered with snow than in the hottest summer; nor did rain or snow in the least hinder their appearance; but, on the contrary, they were observed more frequently, and cast a stronger light in rainy and wet weather; nor were they much affected by the wind.

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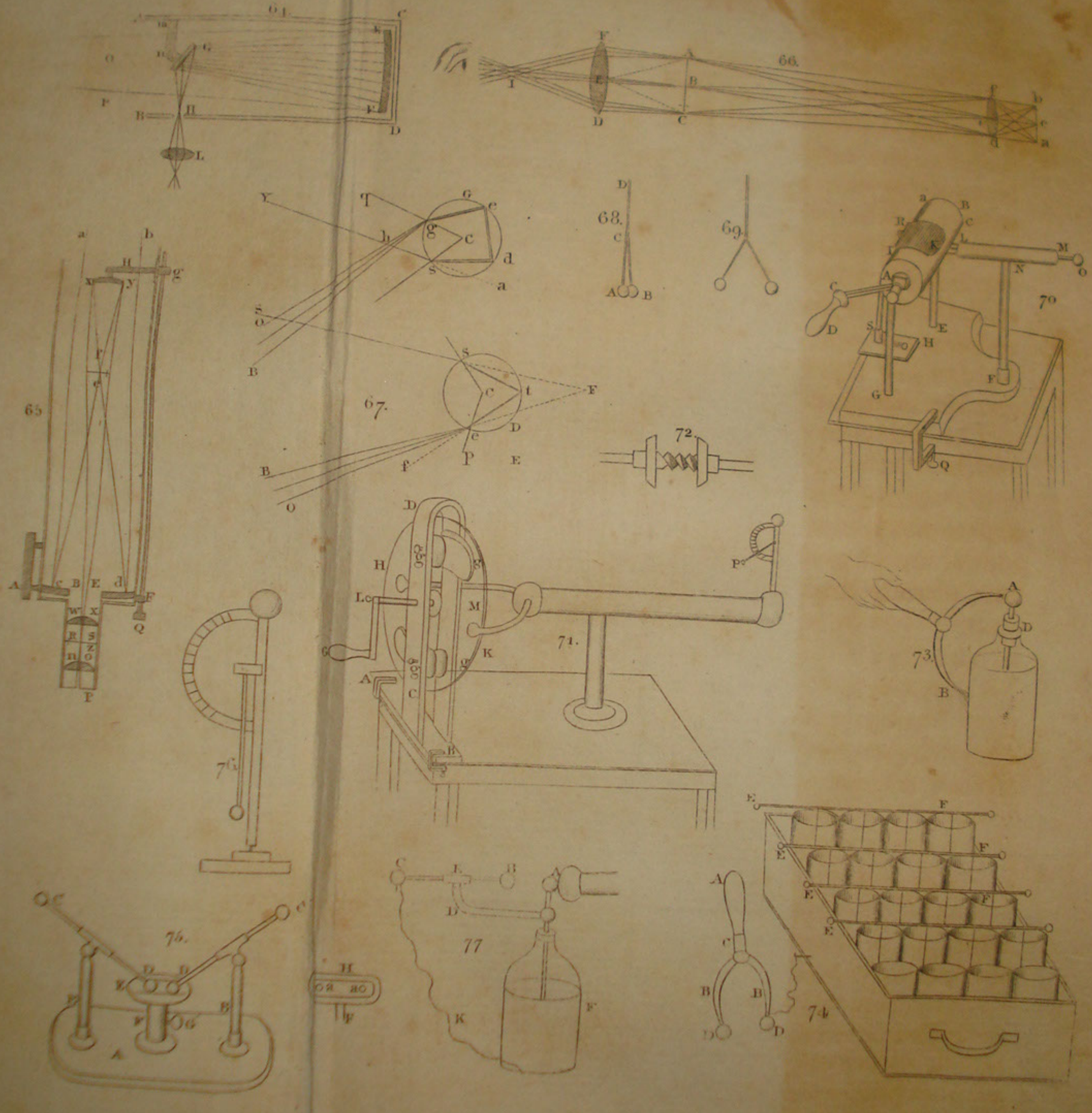

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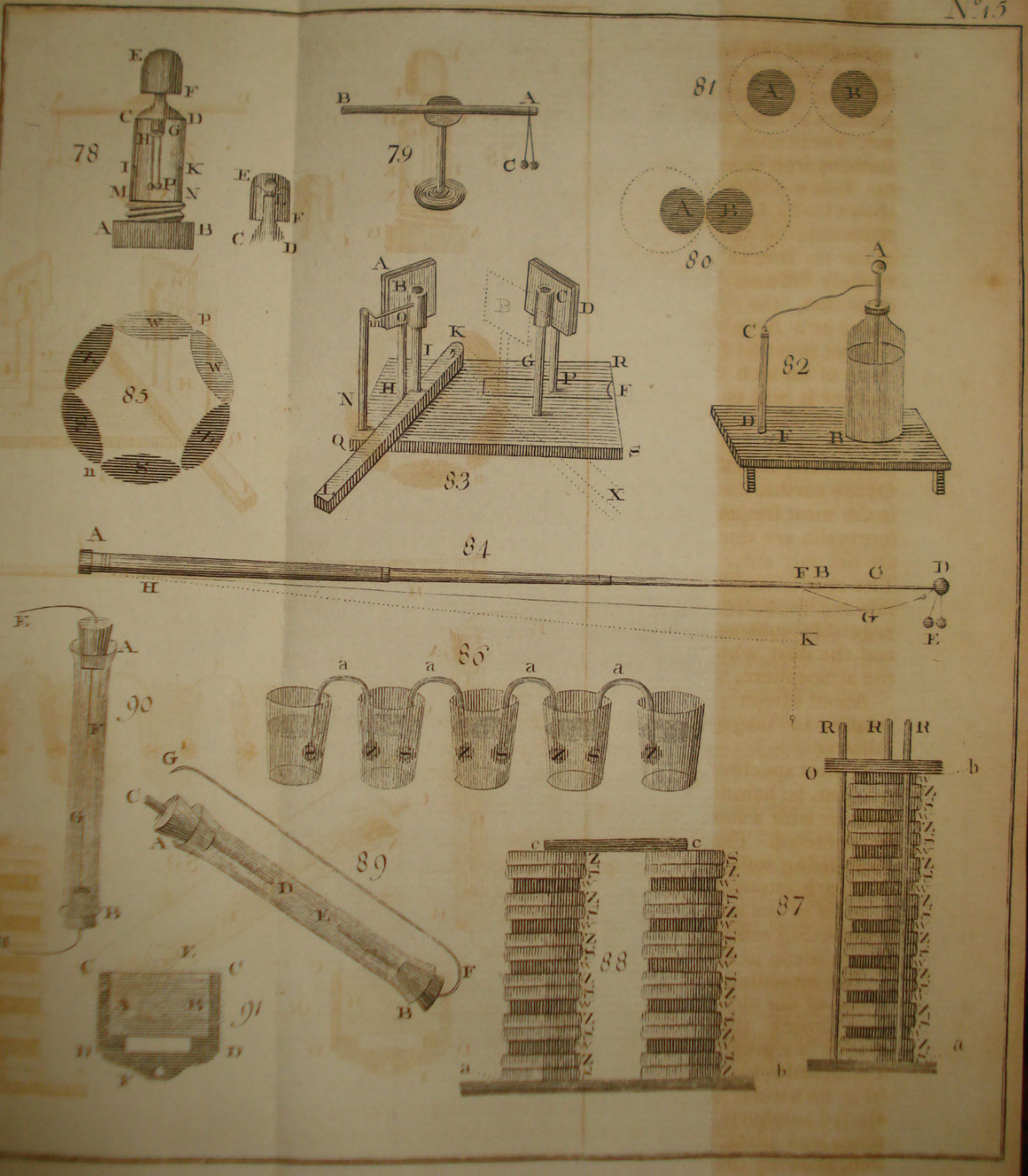

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